374/444

85-027065/05
HITACHI KK
K05
HITA 30.05.83
30.05.83-JP-096694 (12.12.84) G21c-03/30 G21d-03
*J5 9220-686-A
K(5-B3)
031

Fuel assembly for nuclear reactor - has water rod(s) including system for regulating cooling water flow through rod(s) to control steam voids

C85-011475

Fuel assembly comprises at least one water rod which includes means for regulating the flow of cooling water flowing through the rod, thereby controlling steam voids in the rod. At the early stage of fuel consumption, the steam void is allowed to expand in the water rod to harden the neutron spectrum so that more plutonium may be accumulated. At the late stage of fuel combustion, the cooling water is filled in the water rod to remove the steam void and increase a neutron moderator so that the reaction may be accelerated.

USE/ADVANTAGE - This method of operating a nuclear reactor using the fuel assembly utilises the hardening of neutron spectrum to enhance fuel economy. (6pp Dwg.No.0/6)

translation attached

⑲ 日本国特許庁 (JP)　　⑪ 特許出願公開

⑫ 公開特許公報 (A)　　昭59—220686

⑤Int. Cl.³　識別記号　庁内整理番号　㊸公開　昭和59年(1984)12月12日
G 21 D 3/00　　A 7156—2G
G 21 C 3/30　　7808—2G

発明の数 2
審査請求 未請求

(全 6 頁)

⑭原子炉の運転方法及び原子炉用燃料集合体

㉑特　　願　昭58—96694
㉒出　　願　昭58(1983)5月30日
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明　細　書

発明の名称　原子炉の運転方法及び原子炉用燃料集合体

特許請求の範囲

1．炉心内の蒸気ボイドの割合を増加させ中性子スペクトルシフトを利用する原子炉の運転方法において、燃料の燃焼初期には燃料集合体中の水ロッド内に蒸気ボイドを充満させて中性子スペクトル硬化によりプルトニウムの蓄積を増大させ、燃焼後期には前記水ロッド内に冷却水を充満させて反応度を増加させることを特徴とする原子炉の運転方法。

2．内部を冷却水が通過可能な水ロッドを少なくも1個含む原子炉用燃料集合体において、前記水ロッドが前記冷却水の流入量を調整して内部に発生する蒸気ボイド量の調整可能な流量調整部を有することを特徴とする原子炉用燃料集合体。

3．前記水ロッドが、燃料下部タイプレートの付近に前記流量調整部を有する水ロッドである特許請求の範囲第2項記載の原子炉用燃料集合体。

4．前記流量調整部が、前記水ロッド下端の端栓部に設けられた流路の大きさを調整する手段である特許請求の範囲第2項又は第3項記載の原子炉用燃料集合体。

5．前記水ロッドが、上端部の冷却水流出入口部より冷却水を前記水ロッド内壁面に沿つて流通させる仕切り板を有している特許請求の範囲第2項又は第3項又は第4項記載の原子炉燃料集合体。

発明の詳細な説明

〔発明の利用分野〕

本発明は、原子炉、特に軽水冷却型原子炉の運転方法及びこの運転に使用する原子炉用燃料集合体に関するものである。

〔発明の背景〕

第1図は沸騰水型原子炉用の従来の燃料集合体の全体構成を示す説明図、第2図はその下部の要部切欠き断面図で、1は燃料棒、2は水ロッド、3は下部タイプレイト、4は燃料棒下部端栓、5は水ロッド下部端栓、6は水ロッド2の冷却水流入口、7は水ロッド2の冷却水流出口を示してお

り、燃料棒1及び水ロッド2はそれぞれ燃料棒下部端栓4及び水ロッド下部端栓5を通して下部タイプレイト3に支持されている。

この燃料集合体の水ロッド2の冷却水流入口6及び冷却水流出口7は、水ロッド2内に蒸気ボイドが発生しない程度に冷却水が流入するような大きさの孔から構成されている。

このような沸騰水型原子炉では、軸方向にボイド分布を有するため、運転が進むに従つて、炉心上部に比べ炉心下部における中性子の熱化が進み、出力ピークの位置が炉心下部に移動し歪んでくる。また、炉心横断面でみると、バイパス部の減速材により出力ピークは燃料周辺部にあるので、燃料健全性の確保とプラント利用率向上の観点から、出力ピークをできるだけ低下させ、線出力密度を低く抑える設計が講じられている。

これに対して、近年の燃料技術開発の結果、PCI(燃料一被覆管作用)に対する対策の講じられたバリア燃料等を用いることができるようになつたため、これまでのような出力分布の平坦化は特に必要がなくなり、線出力密度については燃料の健全性が維持できる範囲内で上昇させることができるため、PCI対策の講じられた炉心では新しい炉心設計が考えられている。

スペクトルシフト運転法もその一つで、この運転法では、炉心内の蒸気ボイドの割合を増加させるか、あるいは冷却水の割合を減少させることにより、中性子減速機能を弱め、高エネルギー中性子束の割合を増し、所謂、中性子のエネルギースペクトルを硬化させ、プルトニウムの蓄積を増加させて燃料経済性の向上を図つている。

また、加圧水型原子炉では、制御棒として中性子高吸収材を含まず冷却水を排除するための水排除用制御棒を用いている。そしてこの水排除用制御棒を、燃焼初期には炉心に挿入して水対ウラン比を減少させ、スペクトルシフト効果によりプルトニウム生成量を高め、燃焼後半においては炉心から引き抜いて水対ウラン比を増加させ、反応度を高める運転法が考えられている。

〔発明の目的〕

本発明は、軽水冷却型原子炉における中性子スペクトルシフト効果を増大させ、これによつて燃料経済性の向上する原子炉の運転方法を提供することを目的とするものである。

〔発明の概要〕

本発明は炉心内の蒸気ボイドの割合を増加させ中性子スペクトルシフトを利用する原子炉の運転方法において、燃料の燃焼初期には燃料集合体中の水ロッド内の蒸気ボイドを充満させて中性子スペクトル硬化によりプルトニウムの蓄積を増大させ、燃焼後期には前記水ロッド内に冷却水を充満させて反応度を増加させることを第1の特徴とし、内部を冷却水が通過可能な水ロッドを少なくとも1個含む原子炉用燃料集合体において、前記水ロッドが前記冷却水の流入量を調整して内部に発生する蒸気ボイド量の調整可能な流量調整部を有することを第2の特徴とするものである。

例えば、沸騰水型原子炉では、原子炉運転中にボイドが発生し、高いボイド率で運転された燃料集合体は低いボイド率で運転された燃料集合体よりも中性子スペクトルが硬化するためプルトニウムの蓄積が多くなる。この効果は高いボイド率での燃焼期間に比例して増大する。

本発明はこの点に着目し、燃料集合体構成材の一つである水ロッド内の蒸気ボイド率を制御することにより、燃料の燃焼初期においてはボイド率を大きくすることによりプルトニウムの蓄積を増大させ、燃焼後期においてはボイド率をゼロとし中性子減速材の増加させプルトニウムの蓄積の効果と合まつて反応度を増加させ、燃料燃焼度増加が可能な燃料集合体を提供し、所期の目的とする原子炉の運転方法を提供可能としたものである。

〔発明の実施例〕

第3図は本発明の原子炉用燃料集合体の一実施例で用いる水ロッドの要部切欠き断面を示す。この図で、8は水ロッド本体部、9は下部端栓、10は下部端栓9に設けてある冷却水流路、11は小流路付きねじ、12は冷却水流出口を示している。この水ロッドでは冷却水は小流路付きねじ11の小流路より流入し水ロッド本体部8を通り

冷却水流出口12より流出する。そして冷却水は水ロッド本体部8を通る間に加熱され蒸気ボイドを発生し、冷却水の流入量が少ないとボイド率は大きくなり、冷却水の流入量を増加させるとボイド率は小さくなり、さらに冷却水流量を増加させるとボイド率を0とすることも可能である。また小流路付きねじ11の小流路を閉塞すれば水ロッド本体部8の内部は水ボイドで充満し、ボイドの流出した分だけ冷却水流出口12より冷却水が流入する。

すなわち、この水ロッドは小流路付きねじ11をはめてある場合には冷却水流量が少なく、水ロッド本体部8内のボイド率は大きくなり、逆に小流路付きねじ11をはずすと冷却水流量が増大しボイド率を0にすることが可能である。

第4図はこのような水ロッドを有する原子炉用燃料集合体を装荷した炉心の構成の一例を示すもので、この図を用いてこの発明の原子炉の運転方法の一実施例を説明する。この炉心を構成する燃料集合体において、1は装荷後のサイクル経過が1サイクル目(未満)の燃料集合体、2,3及び4は同様に2,3,4サイクル目(未満)の燃料集合体で、1及び2の燃料集合体中の水ロッドは小流路付きねじが取りつけてあり、3及び4の燃料集合体中の水ロッドは小流路付きねじが取りはずしてある。

このように構成されている炉心の無限増倍率を示したのが第5図で、横軸にはサイクル数、縦軸には無限増倍率がとつてある。Aが実施例の場合、Bが水対ウラン比一定で燃焼させた従来の運転方法の場合を示しており、直線XYの左側では小流路付きねじの取りつけられている水ロッド、右側では小流路付きねじの取りはずされている水ロッドが用いられている。すなわち、燃料集合体の反応度が大きい第1,第2サイクル目までは、小流路付きねじにより冷却水流入量を制限し、水ロッド本体部に蒸気ボイドを発生させてプルトニウムを蓄積させ、第3サイクル目からは小流路付きねじを取りはずすことにより、水ロッド本体部に冷却水を充満させ反応度をあげると同時に、1,2サイクル目におけるプルトニウム蓄積の効果による反応度増加が得られるようになつている。

以上の実施例では小流路付きのねじを用いたが小流路なしのねじを用いてもよい。

また、この水ロッドは加圧水型原子炉の燃料集合体にも同様に用いて、同様の効果を得ることができる。

この実施例によれば、軽水冷却型原子炉における中性子スペクトルシフト効果を増大させることが可能であり、これによつて燃料集合体の取り出し燃焼度を増加させ、燃料経済性を向上させることができる。

また、特別な充塡材を用いて、中性子減速効果を減少させるわけではないので、充塡材の中性子吸収による経済性低下及び充塡材使用による廃棄物の増加をまねくことはない。

水ロッドの他の実施例としては、ねじを設けずにめくら栓にするか又は小孔のみ設けておき、第3サイクル目で冷却水流入量を増加させるのには、ドリルで孔をあけるか又は孔を大きくするようにしてもよい。

第6図(a)は水ロッドの他の実施例の要部切欠き断面を示している。この図で、8は水ロッド本体部、13は下部端栓、14は冷却水流入路、15は冷却水又は蒸気の流出入口、17は第6図(b)にその外観を示すような円筒状の仕切り板、17は仕切り板16に設けられている冷却水又は蒸気ボイドの流出流入用の孔を示している。

このような構造の水ロッドは、燃料の燃焼初期には冷却水流入路14の先端は閉塞されているので、冷却水又は蒸気の流出入口15からの水ロッド本体部8内の蒸気流出に応じた冷却水量がこの流出入口15から流入するが、この水ロッド本体部8内には仕切り板16が設けられているので、冷却水は水ロッド内壁にそつて落下しながら蒸発する。

そして燃料集合体燃焼後期においては、下部端栓13の先端部に孔をあけることにより冷却水流入路14から冷却水を水ロッド内に充満させる。下部端栓の先端部をねじで閉塞しておくようにし

てもよい。

この実施例では、水ロッド内のボイド率をさらに高くすることができ、スペクトルシフト効果が一層大きくなる。

〔発明の効果〕

本発明は、軽水冷却型原子炉における中性子スペクトルシフト効果を増大させ、これによつて燃料経済性の向上する原子炉の運転方法を提供可能とするもので、産業上の効果の大なるものである。

図面の簡単な説明

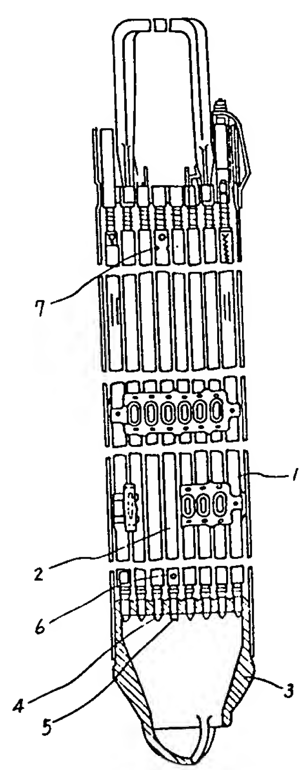
第1図は沸騰水型原子炉用の従来の燃料集合体の全体構成を示す説明図、第2図は第1図の下部の要部切欠き断面図、第3図は本発明の原子炉用燃料集合体の一実施例の要部切欠き断面図、第4図は第3図の原子炉用燃料集合体を装荷した炉心の構成の一例の説明図、第5図は第4図の構成の炉心の効果を従来の構成の炉心の効果と比較して示す特性線図、第6図(a)は第3図と同じく他の実施例の要部切欠き断面図、第6図(b)は第6図(a)の要部の外観図である。

8…水ロッド本体部、9…下部端栓、10…冷却水流路、11…小流路付きねじ、12…冷却水流出口。

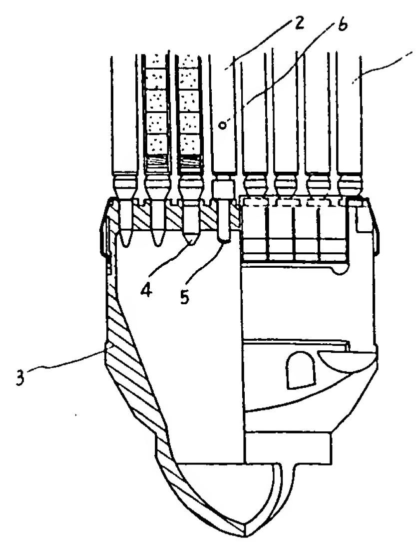
代理人　弁理士　長崎博男

（ほか1名）

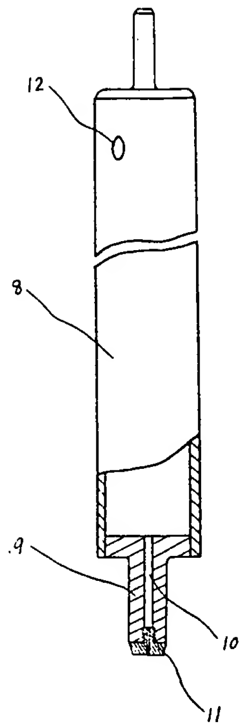
第1図



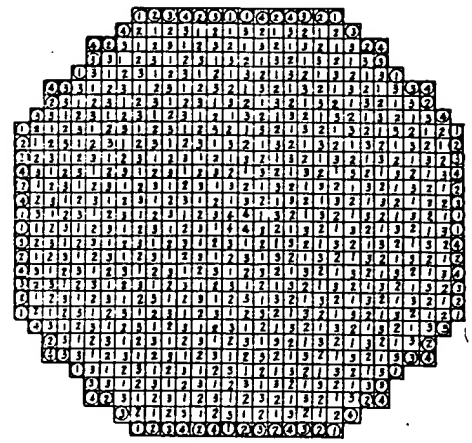
第2図



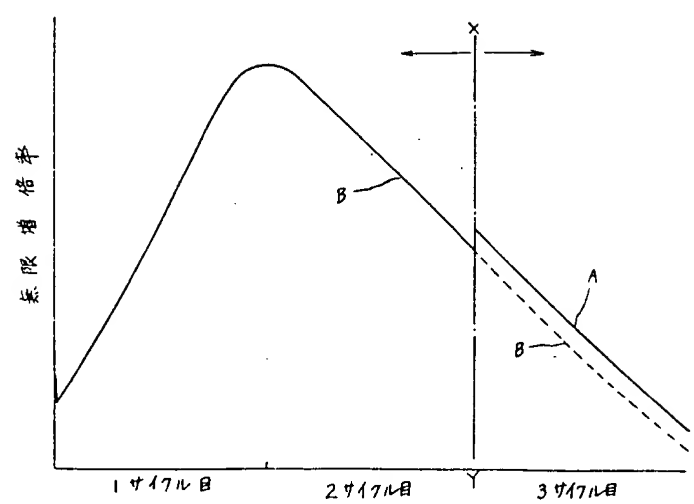
第 3 図



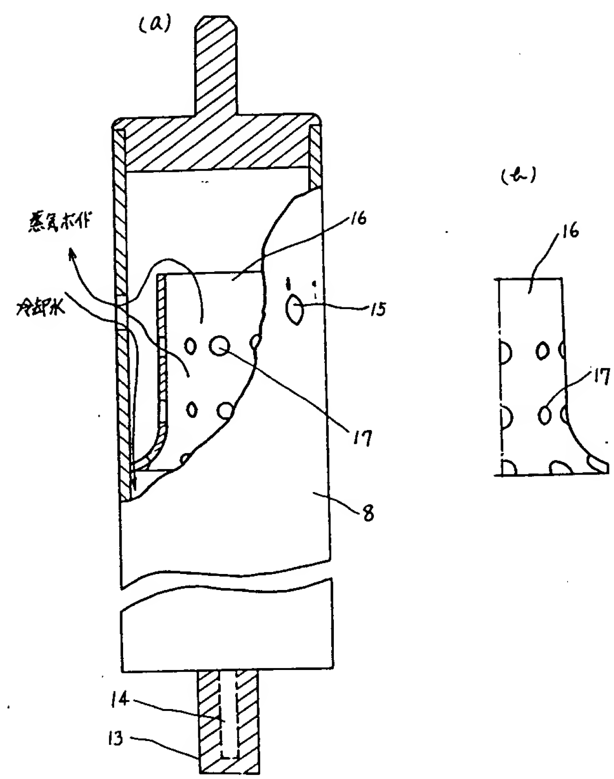
第 4 図

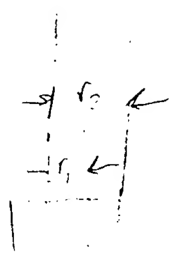


第 5 図



第 6 図





$r_2 \leq 1.4\, r_1$

PTO-91-2509

Japanese Kokai Patent No.
Sho 59[1984]-220686

OPERATING METHOD OF NUCLEAR REACTOR AND FUEL ASSEMBLY FOR NUCLEAR REACTOR

Shiro Nakamura, et al.

UNITED STATES PATENT AND TRADEMARK OFFICE
WASHINGTON, D.C. March, 1991

Code: PTO-91-2509

JAPANESE PATENT OFFICE

PATENT JOURNAL

KOKAI PATENT NO. SHO 59[1984]-220686

Int. Cl.^{3}:	G 21 D 3/00 G 21 C 3/30
Sequence Nos. for Office Use:	A 7156-2G 7808-2G
Application No.:	Sho 58[1983]-96694
Application Date:	May 30, 1983
Publication Date:	December 12, 1984
No. of Inventions:	2 (Total of 6 pages)
Examination Request:	Not requested

OPERATING METHOD OF NUCLEAR REACTOR AND FUEL ASSEMBLY FOR NUCLEAR REACTOR

[Genshiro no untenhoho oyobi genshiroyoneuryo shugotai]

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Agent:	Hiroh Nagasaki, patent attorney, and one other

Title of the invention

Operating method of nuclear reactor and fuel assembly for nuclear reactor

Claims

1. A method for operating a nuclear reactor by increasing the proportion of the vapor void in the reactor core and using the neutron spectral shift; method characterized by filling the vapor void in the water rods in the fuel assembly during the initial phase of combustion of the fuel to increase the accumulation of plutonium by neutron spectral hardening, and filling the water coolant in said water rod in the later phase of combustion to increase the degree of reaction.

2. A fuel assembly for nuclear reactor that contains at least one water rod that permits passage of water coolant through the interior, where said water rod has a flow rate regulating member to permit regulation of the amount of vapor void generated in the interior by regulating the rate of inflow of said water coolant.

3. The fuel assembly for nuclear reactor according to Claim 2, where said water rod has the said flow rate regulating member near the tie plate located below the fuel.

4. The fuel assembly for nuclear reactor according to Claim 2 or Claim 3, where said flow rate regulating member is a means to regulate the size of the flow rate being provided at the end plug part located on the lower end of said water rod.

5. The fuel assembly for nuclear reactor according to Claim 2, Claim 3 or Claim 4, where said water rod has a separator plate that permits the water coolant to flow from the outflow entrance of the water coolant located at the upper end along the inner wall surface of said water rod.

Specification

Industrial application field

This invention relates to the operating method of nuclear reactor, particularly the operating method of nuclear reactor of the type which is cooled by light water [^1H_2O], and also to the fuel assembly for the nuclear reactor.

Background of invention

Fig. 1 is a diagram that illustrates the entire configuration of the conventional fuel assembly for boiling water type nuclear reactor, and Fig. 2 is a partial sectional view of the essential parts located thereunder, where (1) is a fuel rod, (2) is a water rod, (3) a lower tie plate, (4) a lower end plug of the fuel rod, (5) a lower end plug of water rod, (6) a water coolant inflow entrance of water rod (2), and (7) is a water coolant outflow exit of water rod (2). The fuel rods (1) and water rods (2) are supported by the lower tie plates (3), respectively, through the lower end plug (4) or the fuel rods and the lower end plug (5) of water rods.

The water coolant inflow entrance (6) and water coolant outflow exit (7) of the water rod (2) of this fuel assembly are holes of such size as to allow inflow of water coolant so as not to create vapor void in the water rod (2).

Since there is a void distribution in the axial direction of this type of boiling water type nuclear reactor, generation of heat from neutrons will progress in the lower part of the nuclear core rather than the upper part of the nuclear core, as the operation of the reactor continues; as a result, the output peak will shift to the lower part of the nuclear core, distorting the situation. And, if we look at the transverse cross section of the nuclear core, since the output peak is located in the peripheral area of the fuel, due to the presence of decelerating material of the bypass part, design is made in such a way to lower as much as possible the output peak and to suppress the radiation output density to a lower level, from the viewpoint of improving the rate of use of the plant and maintaining the safety of the fuel.

As a result of development of fuel technology in recent years, which allows use of a barrier fuel, etc., against PCI (fuel - cover tube action), there is no longer a necessity to normalize the output distribution, which was required in the past. Thus, since it is now possible to raise the radiation output density within the range that allows maintenance of the safety of the fuel, a new nuclear core design is being contemplated for the reactor core, which was designed against PCI in the past.

The spectral shift operation method is one of them. With this operating method, either the proportion of the vapor void in

the nuclear core is increased or the proportion of the water coolant is reduced, to weaken the neutron deceleration function and to increase the proportion of the high energy neutron flux, to harden the so-called neutron energy spectra and to improve fuel economy by increasing the accumulation of plutonium.

And with the nuclear reactor of the type that uses water under pressure, a water exclusion control rod, which does not contain neutron absorbing material and can exclude water coolant, is used as the control rod. This water exclusion control rod is inserted into the nuclear core during the initial phase of combustion to reduce the water/uranium ratio and to raise the amount of plutonium being formed; then the water/uranium ratio is increased by withdrawing the rod from the reactor core to raise the degree of reaction in the later phase of the combustion. Such operation method is being contemplated.

Object of the invention

The object of this invention is to provide an operation method of nuclear reactor that increases the neutron spectral shift effect in the light water cooling type nuclear reactor for improvement of fuel economy.

Summary of the invention

This invention is a method for operating a nuclear reactor by increasing the proportion of the vapor void in the reactor core and using the neutron spectral shift; the method is characterized by filling the vapor void in the water rods in the

fuel assembly during the initial phase of combustion of the fuel to increase the accumulation of plutonium by neutron spectral hardening, and filling the water coolant in said water rod in the later phase of combustion to increase the degree of reaction. The second feature of this invention is a fuel assembly for nuclear reactor that contains at least one water rod that permits passage of water coolant through the interior, where said water rod has a flow rate regulating member to permit regulation of the amount of vapor void generated within by regulating the rate of inflow of said water coolant.

For example, in the boiling water type nuclear reactor, void is created during the operation of the nuclear reactor, and the neutron spectra of the fuel assembly being operated at high void ratio will be hardened more than the fuel assembly being operated at lower void ratio; as a result, more plutonium will accumulate. This effect increases in proportion to the period of combustion at high void ratio.

This invention has focussed its attention on this point. Thus, by controlling the vapor void ratio in the water rod, which is one of the main elements of the fuel assembly, accumulation of plutonium is increased by increasing the void ratio in the initial phase of the combustion of fuel, and the degree of reaction is increased together with the accumulation of plutonium by reducing the void ratio to zero, and by increasing neutron deceleration material in the later phase of combustion. Thus, this invention provides a fuel assembly that permits to increase the degree of fuel combustion, and also provides a method for operating a nuclear reactor, which was the original goal.

Examples of the invention

Fig. 3 illustrates a partial sectional view of the essential parts of the water rod being used in an example of the fuel assembly in this invention for nuclear reactor. In this diagram, (8) is the main body of the water rod, (9) a lower end plug, (10) a water coolant flow route being provided in the lower end plug (9), (11) is a screw with small flow path, and (12) illustrates the water coolant outflow exit. In this water rod, the water coolant enters from the small flow path of the screw (11) with a small flow path, moves through the main body (8) of the water rod, and exits through the water coolant outflow exit (12). As the water coolant moves through the main body (8) of the water rod, it is heated to create a vapor void. If the flow rate of the water coolant is low, void ratio will become larger. If the amount of inflow of water coolant is increased, the void ratio decreases. And if the amount of inflow of water coolant is increased further, it is possible to bring down the void ratio to zero. If the small flow path of the screw (11) with the small flow path is closed, the interior of the main body (8) of the water rod will be filled with water void, and water coolant will flow in through the water coolant outflow exit (12) by as much as the portion of the outflow of the void.

Thus, with this water rod, if there is a screw (11) with small flow path, the flow rate of water coolant will decrease and the void ratio in the main body (8) of the water rod will increase. On the contrary, if the screw (11) with the small flow path is removed, the flow rate of the water coolant increases and therefore it is possible to bring the void ratio down to zero.

Fig. 4 illustrates an example of the configuration of the reactor core, which is loaded with the reactor fuel assembly that has such water rod. Let us use this diagram to explain an example of the operating method of this invention for the nuclear reactor. In the fuel assembly that constitutes this reactor core, (1) is a fuel assembly at the first cycle (or less) after loading, and (2), (3), and (4) are, likewise, the fuel assemblies at the second, third and fourth cycles (or less). A screw with a small flow path is mounted in the water rod of the fuel assemblies (1) and (2), and the screw with small flow path is removed from the water rod in the fuel assemblies (3) and (4).

Infinite amplification ratio of the reactor core, which is configured in the aforementioned manner, is illustrated in Fig. 5, where the abscissa represents the cycle number and the ordinate represents the infinite amplification (or multiplication) ratio. A illustrates an example of this invention, and B illustrates an example of conventional operating method by combustion at a constant water/uranium ratio. On the left side of the straight line X-Y, the water rod mounted with a small flow path screw is used, and on the right side of the straight line X-Y, the water rod without this screw is used. Thus, until the first and second cycle that showed a high degree of reaction of the fuel assembly, the small flow path screw is used to limit the amount of inflow of the water coolant, to generate vapor void in the main body of the water rod, so that plutonium will accumulate. Starting from the third cycle, the degree of reaction is raised by removing the small flow path screw to fill the water coolant in the main body of the water rod, so that, together with the effect of accumulation of

plutonium in the first and second cycles, the degree of reaction can be increased.

Although a screw with a small flow path was used in the aforementioned example, a screw without a small flow path may be used also.

This water rod can be used similarly in the fuel assembly of the pressurized water type nuclear reactor, to create a similar effect.

According to this example, it is possible to increase the neutron spectral shift effect in the light water cooling type nuclear reactor, with which the degree of takeout combustion of fuel combustion can be increased and fuel economy can be improved.

And, since this invention is not an attempt to reduce the neutron deceleration effect by using a special filler, it will never invite decrease of fuel economy caused by absorption of neutrons by the filler and increase of water due to use of filler.

Another example of water rod is as follows. A blind plug or a small hole alone may be provided without a screw, and a hole may be drilled or the hole size may be increased, to increase the amount of inflow of the water coolant in the third cycle.

Fig. 6(a) illustrates a partial sectional view of the essential part of another example of the water rod. In this Fig. 6(a), (8) is the main body of the water rod, (13) a lower end plug, (14) a water coolant inflow path, (15) a water coolant or vapor outflow entrance, and (16) is the separator plate whose external outlook is illustrated in Fig. 6(b), and (17) is the

hole for outflow/inflow of water coolant vapor void being provided in the separator plate (16).

Since the tip of the water coolant flow path (14) of the water rod having such configuration is closed in the initial phase of combustion of the fuel, such amount of water coolant that corresponds to the outflow of the vapor in the main body (8) of the water rod flows in from the water coolant or vapor outflow entrance (15). However, since the separate plate (16) is provided in the main body (8) of the water rod, the water coolant will drip along the inner wall of the water rod and evaporate.

In the later phase of the combustion of fuel assembly, a hole at the tip portion of the lower end plug (13) allows the water coolant to fill the interior of the water rod through the water coolant inflow path (14). It may be designed in such a way that the tip portion of the lower end plug is closed by a screw.

In this invention, void ratio in the water rod can be raised further, which will further increase the spectral shift effect.

Effect of invention

This invention provides a method for operating a nuclear reactor that can increase the neutron spectral shift effect in the light water cooling type nuclear reactor, improving fuel economy. Thus, this invention has a significant commercial effect.

<u>Brief explanation of the drawings</u>

Fig. 1 is a schematic diagram to illustrate the entire configuration of the conventional fuel assembly for the boiling water type nuclear reactor; Fig. 2 is a partial sectional view of the essential part of the lower part of Fig. 1; Fig. 3 is a partial sectioned view of the essential part of an example of the fuel assembly of this invention for nuclear reactor; Fig. 4 is a schematic diagram of an example of the nuclear core configuration, which is loaded with the fuel assembly for the nuclear reactor illustrated in Fig. 3; Fig. 5 is a characteristic radiation diagram to compare the effect of the nuclear core of the conventional configuration; Fig. 6(a) is the partial sectioned view of the essential part of another example, like Fig. 3; and Fig. 6(b) is an external view of the essential part of Fig. 6(a).

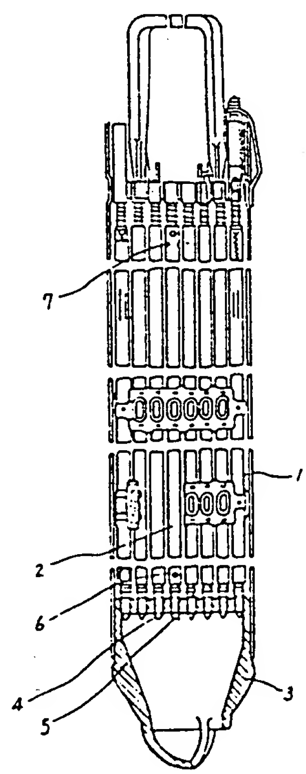


Figure 1.

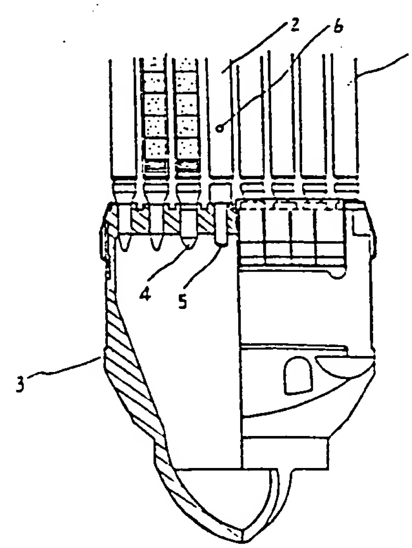
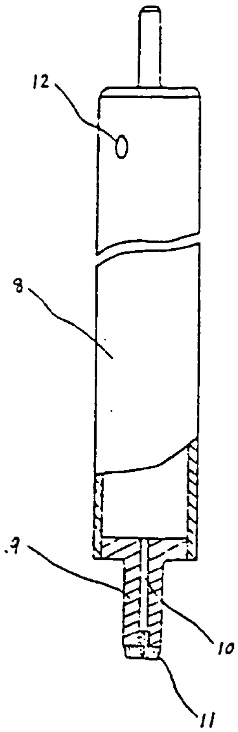


Figure 2.



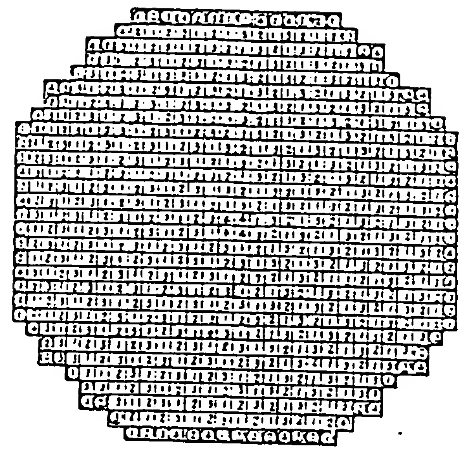


Figure 3.

Figure 4.

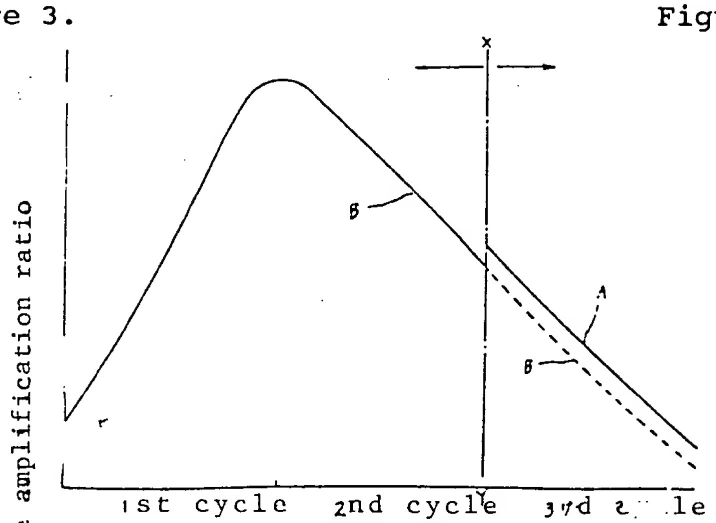


Figure 5.

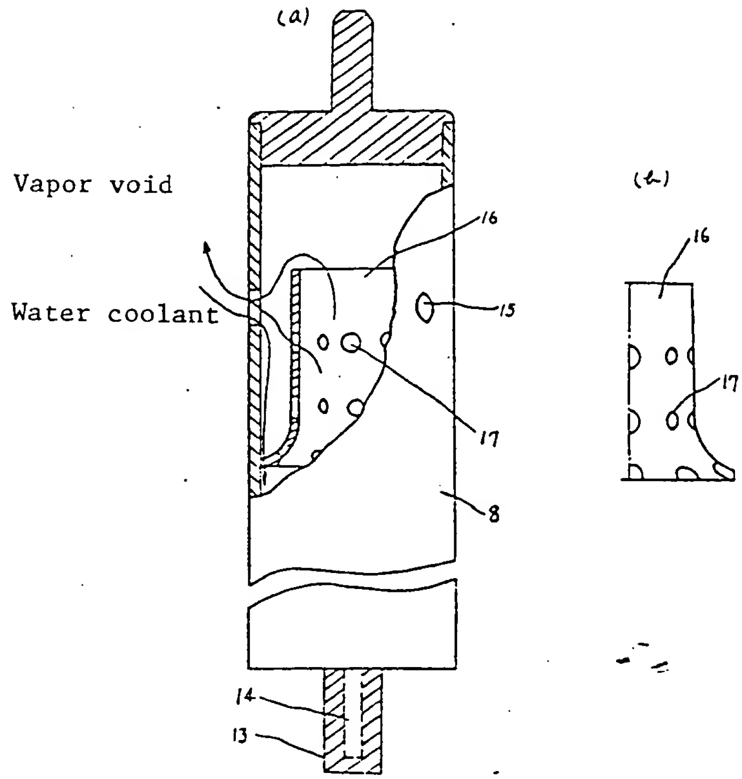


Figure 6.